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THE PLANT DISEASE REPORTER

Issued By

THE PLANT DISEASE SURVEY

Division of Mycology and Disease Survey

BUREAU OF PLANT INDUSTRY, SOILS, AND AGRICULTURAL ENGINEERING

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PLANT PATHOLOGICAL INVESTIGATION
IN THE UNITED STATES
IV

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The Plant Disease Reporter is issued as a service to plant pathologists throughout the United States. It contains reports, summaries, observations, and comments submitted voluntarily by qualified observers. These reports often are in the form of suggestions, queries, and opinions, frequently purely tentative, offered for consideration or discussion rather than as matters of established fact. In accepting and publishing this material the Division of Mycology and Disease Survey serves merely as an informational clearing house. It does not assume responsibility for the subject matter.

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THE PLANT DISEASE SURVEY
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Plant Industry Station Beltsville, Maryland

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PLANT DISEASE RESEARCH AND EXTENSION IN IOWA

W. F. Buchholtz and J. R. Wallin

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W. F. Buchholtz and J. R. Wallin*

Development and growth of plant disease research and extension in Iowa has been concurrent with the growth and development of the Iowa State College. In keeping with the increasing service of that institution to the agriculture of Iowa and the Nation, the activities of its plant pathologists have been directed toward that objective of service.

The research program has been developed and organized to cope most effectively with disease problems as they have arisen. As a particular plant disease research program was organized and developed, it became known and designated by the staff as the "crown rust program", "corn disease program", "seed treatment program", "watermelon wilt program", "root necrosis program", etc. Certain aspects of such major research programs are listed and briefly discussed in this presentation.

MAJOR FIELDS OF RESEARCH OF LONG DURATION

A record of plant disease research in Iowa should perhaps begin with recognition of early observations and descriptive contributions by L. H. Pammel. As a diligent student of the indigenous and economic plants of Iowa, he was very much aware of their maladies, and took time to record and describe some of them and to teach others to do likewise. Two of his noteworthy contributions were the description of Xanthomonas (Bacillus) campestris as the cause of black rot of rutabaga in 1895 (67) and the description of Helminthosporium sativum (with King and Bakke) as the cause of barley blight (68) in 1910.

Under Pammel in the Department of Botany, I. E. Melhus began his service to Iowa State College as plant pathologist in 1916. His appointment marked the beginning of an intensive effort in plant disease research and teaching which, as the staff and the College grew, resulted in the major research and extension programs which are summarized in this discussion.

CROWN RUST OF OATS: -- Oats has come to be Iowa's major small grain crop, and Puccinia coronata has been the oat crop's most damaging and persistent pathogen. The Iowa Agricultural Experiment Station has carried forward a crown rust research program continuously for many years. I. E. Melhus inaugurated the project in 1914 and has maintained an effective constant interest in it. Such able investigators as J. H. Parker, L. W. Durrell, Florence Willey, L. D. Leach, S. M. Dietz and H. C. Murphy have been associated with or in charge of the project. The U. S. Department of Agriculture has cooperated with the Iowa Station ever since the initiation of this work. As a Federal employee, S. M. Dietz was in charge during the ten-year period 1917 to 1927. In 1928, H. C. Murphy assumed responsibility for the project and since then has carried it forward, along with some consideration of other oat pathogens, notably Helminthosporium victoriae. Breeding for crown rust-resistance has been in cooperation with plant breeders at the Iowa Station.

Early accomplishments were a clear definition of the crown rust problem (50), determination of the Rhamnus host range of P. coronata (49), recognition of the phenomenon of specialization in P. coronata (49, 60), and the incorporation of the Green Russian type of resistance into such strains as D67 and D69 (11), which served as useful parents in the later resistance program.

A landmark of progress was the discovery, in 1929 (63) and 1931 (96), of the lines, Victoria and Bond, respectively, whose crown rust- and smut-resistance were combined with the stem rust-resistance of Richland (97), Iogold, and D69 (64). The Victoria-Richland varieties, Boone, Tama and Control, were made available to Iowa farmers in 1941, and by 1945 constituted an estimated 98 percent of the Iowa oat acreage. Clinton, the result of a D69-Bond cross (61), was first grown in 1945, and by 1950 Clinton and other derivatives of this cross constituted about 95 percent of the Iowa acreage.

According to a recent conservative estimate, since 1941 Iowa farmers have produced 255,500,000 bushels more oats by growing these crown rust-resistant varieties.

Change in the race constitution of P. coronata may force a change from the varieties carrying the resistance of Bond. Varieties are in the making carrying the resistance of such varieties as Landhafer, Santa Fe, Trispernia, and Ukraine to the now prevalent crown rust races that parasitize Clinton and other Bond derivatives. The Rhamnus host range of these races is in

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* C. S. Reddy, G. Semeniuk, H. C. Murphy, J. C. Gilman, W. J. Hooker, and J. R. Crall provided very useful information and suggestions for this summary.

process of determination. Through the years, the prevalent races of P. coronata have been determined and recorded.

A serious impediment to the crown rust-resistance program was the sudden and destructive outbreak of Helminthosporium victoriae which, during the period 1945, 1946, and 1947, caused as severe damage to Victoria derivatives as had earlier epiphytotics of P. coronata. This unexpected threat was met by definitely ascribing the damage to H. victoriae (42), by promptly ascertaining that the only hosts were Victoria and its derivatives (62), by establishing that susceptibility of these varieties to H. victoriae was irrevocably "linked" to resistance to P. coronata (38), and by revising the crown rust-resistance program to avoid further use of Victoria and its derivatives.

CORN DISEASES: -- Intensive corn disease research at the Iowa Station was begun by I. E. Melhus in 1920, following the early observations made by Pammel and his associates (69, 70). Early associates of Melhus on the corn work were L. W. Durrell, F. H. van Haltern, C. S. Reddy, D. E. Bliss, G. A. Platz, A. H. Eddins, W. P. Raleigh, and Mary F. Howe. In 1937 a full time research position was established and held for one year by G. N. Davis; since 1938 George Semeniuk has held this position and has had responsibility for a major portion of corn disease research, although the importance of the crop in Iowa has been the basis for the continued efforts of Melhus, Reddy and their students. Corn disease research at the Iowa Station has been supported entirely with State and gift funds. The disease resistance aspects have been studied cooperatively with agronomists.

Ear, stalk and root disease investigations have been stressed continuously over the years. The ear rots caused by Diplodia zeae, Gibberella zeae, and Nigrospora oryzae received first attention because of their prevalence and their importance to the selection of ears for seed, (14, 15, 16, 69, 70, 76). Their deleterious effects on the vitality of the seed and on the health of the seedling (14, 77, 79) led to recommendations for their detection and control by seed disinfection (14 54, 76). Cob acidity greater than pH 5.2 (80), characteristic of matured ears (94, 95), and the process of seed germination (80) were found to confer resistance to Nigrospora orzyae. This fungus was found to develop and persist profusely on the rudimentary ears in the lower leaf axils (95).

Stalk rot disease investigations have dealt primarily with Diplodia zeae. Durrell, G. L. McNew and Semeniuk have participated in various phases of the Diplodia problem. Their results showed that the pathogen: (a) infected the plant at the nodes following a period of development on dead pollen lodged between the leaf sheaths and stalks (13); (b) was destructive to seedlings when introduced into the soil (18, 87, 89), and that by this method susceptible single crosses were differentiated (88); and (c) invaded the mesocotyl and crown tissues of young plants but remained inactive until the plants approached maturity (40).

Investigation of root rots, which are of major significance to Iowa corn production, have resulted so far in description of the symptoms produced by Pythium graminicola, Helminthosporium sativum, Gibberella zeae, Rhizoctonia solani and other pathogens (25), and evaluation of seedling resistance of some lines to P. graminicola (25, 93).

Smut has been studied at intervals. Factors influencing spore germination (74), and the pathogenicity of Ustilago zeae (= U. maydis) (17, 73, 119) were the subject of early inquiries. These were followed by development of the fish-oil soap (10) and similar (119) techniques for inducing the passage of a sporidial suspension to the growing point of the young plant via the spiral whorl. The concept of the systemic infection of the corn plant by the smut fungus (10) resulted from use of these techniques and from the observation that rudimentary galls were common at all the nodes of infected plants. New methods of inoculation, by hypodermic injection of sporidial suspensions into the unopened coleoptiles (98) or at the first node of the stem on germinating seed, were devised in the search for a more rapid process of evaluating resistance among lines of corn. The discovery that seedling infection may follow the application of sporidia to germinating seed (111) provided a simple method for inducing seedling infection and demonstrated another avenue through which infection can occur.

Other corn disease contributions include an account of the purple leaf sheath spot of corn (13); experimental demonstration of seedling infection by oospores of Sclerospora graminicola taken from Setaria, and a record of occurrence of this pathogen on corn in Iowa (19, 55, 56); a description of the Holcus leaf spot bacterium (Pseudomonas holci) and the symptoms induced by it (34); and proof that seedlings as well as maturing stalks can be attacked by Sclerotium bataticola (90).

When shelled corn was under loan and seal in steel bins throughout Iowa, the Iowa Station, in cooperation with the Commodity Credit Corporation, made extensive studies of stored corn

deterioration; including those of Semeniuk and associates (66, 91, 92) on the role of molds in stored corn spoilage. The practical result of this research was the realization that moisture contents must be lower than 13.5 percent to permit continuous storage of shelled corn.

One of the major objectives of the Iowa State College Guatemala Tropical Research Center has been to collect disease-resistant corn germ plasm. A large number of collections have been evaluated for resistance in the seedling stage to Pythium graminicola (93), and some for resistance to Helminthosporium turcicum (101). Degrees of H. turcicum and rust attack have been noted on many lines in Guatemala (48).

Because, up to now, no single plant pathogen has been a limiting factor in corn production in Iowa, comparable to Puccinia coronata on oats, it has not been necessary or readily possible to apply the results of corn disease research to crop production so intensively. The potential value of the corn disease knowledge contributed from Iowa and other States and the U. S. Department of Agriculture, however, is available to all those interested in corn. Many corn breeders are aware that corn is "good" partly because it is disease-resistant. Full exploitation of this approach to "corn improvement" remains for the future, but the overall value of what has been accomplished on this important and widely grown crop has already been very substantial.

SEED TREATMENT: -- Plant Pathologists at the Iowa Station have been closely identified with the development of seed treatment as an agricultural practice. Melhus, J. C. Gilman and J. B. Kendrick, in 1920, determined the efficacy of hot formaldehyde in disinfecting potato seed tubers (51). Associates J. J. Wilson, W. P. Raleigh and C. S. Reddy developed Merko and Sterocide as corn seed disinfectants in 1928 and 1930, respectively. With the increased activity of large chemical companies in producing new basic fungicidal compounds, the interest of the Iowa Station turned to evaluation of compounds and formulations and to defining their activity and usefulness under Iowa conditions. Such efforts were stimulated in part by studies of effectiveness of corn seed treatment at different planting rates (81) and at different planting dates, of flax seed treatment at different planting dates (7, 83) and of sugar beet seed treatment (85).

These studies contributed to a growing realization that a fungicide coating can serve as a protectant of the germinating seed against soil-borne pathogens, and that its effectiveness is conditioned by soil temperature and moisture, in a manner and degree depending on the crop. Corn seed, for instance, has been found to be most benefited by seed treatment when subjected to "cold and wet" soil conditions soon after planting (86); likewise flax (83). Field experiments showed that treated seed of corn and flax could be planted with safety somewhat earlier than untreated seed (82, 83), and that seed treatment of relatively disease-free oats seed, by protecting such seed from soil-borne pathogens, resulted in increased yields. During the past ten years, even with relatively disease-free seed, corn and oat yields have been increased an average of more than three bushels per acre by recommended fungicide seed treatments (84).

An unusual by-product of the knowledge that at low temperatures corn seed is attacked by soil-borne organisms has been the "cold-test" for seed corn (86). The fact that high quality corn seed, in addition to being viable, is capable of surviving for a short time in Pythium-infested soil at low temperatures, in contrast to the very rapid deterioration of low quality seed under such circumstances, is now so well recognized that the "cold-test" has become a standard seed laboratory germination and seed treatment evaluation technique. A similar test, in which the seed is flooded at room temperature, is now being developed.

Most of this knowledge has resulted from contributions by Reddy and his associates.

Recently seed treatment research has been directed toward evaluating the role of fungicides in establishing stands of soybeans and small seeded forage legumes and grasses. A beginning has been made in determining their effect on legume root nodulation in Iowa soils.

WATERMELON WILT: -- Devastation of the watermelon industry in southeastern Iowa by the wilt pathogen led to inauguration of the watermelon wilt project in 1925. Under the guidance of Melhus there was first a definition of the problem and a study of the mode of parasitism by Fusarium niveum (75, 120). In 1930 the resistant varieties Iowa Belle, Iowa King, and Pride of Muscatine were available. All were developed by mass selection and selfing within susceptible varieties grown on infested soil. By 1937, Stone Mountain #5 and Kleckley #6 had been developed, both from further exploitation of the same technique. By the back-crossing method, it was possible to combine anthracnose- and wilt-resistance in several lines. One of these is the variety, Black Kleckley. Continued efforts resulted in the production of Kleckley Hybrid (1941) and Dixie Hybrid (1941), the latter an unusually high quality wilt-resistant melon, the first such available to Iowa growers (84).

After twenty years, many southeastern Iowa watermelon growers have turned to other crops. The way to recovery of the industry has been opened, however. Furthermore, wilt- and anthracnose-resistant germ plasm developed in Iowa has been utilized in disease-resistance programs in a number of other States.

NURSERY CROP DISEASES: -- In Shenandoah and Hamburg, in southwestern Iowa, are the headquarters for three large nurseries, one of which is recognized as this country's largest wholesale producer of nursery stock. Several nursery disease problems have been investigated, notably crowngall, cherry leaf spot and mildew, cedar apple rust, damping-off of conifers and other seedlings, and Phomopsis blight of cedar. Interest and activity in solving nursery disease problems has been of 30 years' duration, with some attention being given by Melhus, J. H. Muncie, R. F. Suit, D. E. Bliss, and G. L. McNew. Among the practical results are a clearer definition of the crowngall and callus knot problem (43, 52, 57, 59), apple grafting techniques that limit development of callus knot and crowngall at the graft union (53), satisfactory cherry fungicide sprays for leaf spot and mildew control (41), a record of the seasonal development and pathogenicity of Gymnosporangium in Iowa (3), and a seed-bed treatment for conifer damping-off control. Research contact with the nursery industry has permitted making many suggestions for disease control by practices developed by research other than in Iowa.

SUGAR BEET DISEASE: -- Diseases have been a major factor in the discouragement of sugar beet production in northern Iowa. In an attempt to meet this problem, the Cercospora leaf spot and Aphanomyces root rot diseases were intensively investigated on the Northern Iowa Experimental Association farm at Kanawha, beginning in 1930. E. F. Vestal, F. G. Bell, C. M. Nagel, C. S. Reddy and W. F. Buchholtz have been full or part time workers in this field. Wider spacing with cross-blocking to provide aeration for leaf spot control (103, 65), seed treatment to prevent seed decay and seedling damping-off (35), crop rotation to avoid heavy leaf spot and root rot losses (6), and a means of indexing soil to predict losses from Aphanomyces root rot in a field to be planted to beets (20), are among the practical results of this research.

High returns from unrestricted acreages of corn, soybeans, and crown rust-resistant oats during the 1940's have helped discourage a return to sugar beet production, and varieties somewhat resistant to Cercospora beticola and Aphanomyces cochlioides may be needed to help insure stability, if or when conditions are again favorable to sugar beet production in northern Iowa. The supplementary control practices developed and demonstrated by plant pathologists at the Iowa Station will be valuable.

ROOT NECROSIS: -- For many years an active root necrosis research program has been conducted at the Iowa Station. Early experiences of Melhus, Reddy and others with corn seedling blight and Diplodia stalk rot were a beginning. Work by Buchholtz on sugar beet root rot and sugar beet and legume damping-off (4, 5, 6) emphasized the role of soil-borne phycomycetous pathogens of those crops. Reddy's and his associates' discoveries led to the realization that corn seed rotting in cold soil was by Pythiaceous fungi, (82, 86); Wen-Chun Ho, C. H. Meredith and Melhus demonstrated conclusively that Pythium graminicola was a major pathogen of corn and barley roots (25, 26); A. W. Welch did likewise for P. debaryanum and P. irregulare on oats (117) -- not P. graminicola, which has been repeatedly substantiated by later work; S. G. Younkin's work indicated that "wilt" of very young watermelon seedlings, which was common even with varieties resistant to Fusarium niveum, was probably damping-off by P. irregulare (122). Subsequent work, some of it yet unpublished, has shown that there may be a seasonal variation in the Pythium "content" of infested soil (39); that P. graminicola is most abundant in the upper 12 inches of soil (37); that moisture deficiency accentuates the effect of Pythium injury to barley (39); that with time there is a progressive decrease in occurrence of P. debaryanum and an increase of P. graminicola on barley seedlings and roots, which may be in response to seedling growth as well as to season (100); and that there are measurable differences in susceptibility to P. graminicola between varieties of corn (25, 93), barley (23, 26) and bromegrass (24).

The role of phycomycetous and other root pathogens in crop and variety choice and all aspects of crop production in Iowa is well indicated but not yet fully defined. There seems little doubt that P. graminicola was in large part responsible for failure of the barley crop in Iowa during 1942-1944, and that stability of barley production in Iowa will depend in part on a variety with considerable resistance to this pathogen. The root necrosis research completed and under way enabled realization of that fact and paved the way for the developing of a resistant variety (23).

Root necrosis research is going forward at the Iowa Station.

BACTERIAL PLANT PATHOGENS: -- A broad and flexible program of bacterial disease research has been fostered, not only to permit effective and prompt investigation of timely problems, but also to encourage contributions to an understanding of the basic concepts concerning the bacterial plant pathogens as a group.

Research on the bacterial plant pathogens began with L. H. Pammel's work on Xanthomonas campestris in 1895 (67). From 1919 to 1937, crowngall and hairy root of nursery stock were studied. Investigations on these diseases were stimulated by alarmed Iowa nurserymen who were losing thousands of trees, supposedly because of crowngall. They supported, in part, the crowngall research program in Iowa and Wisconsin through the Crop Protection Institute. In Iowa, I. E. Melhus, J. H. Muncie, Wm. T. H. Ho, M. K. Patel, R. F. Suit and G. C. Kent were associated with either or both crowngall and hairy root investigations.

Briefly, some of the results of these studies were: an improved method of isolating the crowngall bacterium (71); discovery that a high percentage of galls on apple grafts were callus knot rather than crowngall (59); and that callus knot could be reduced by carefully fitted wedge grafts (53); confirmation of Riker and Keitt's earlier report that hairy root was caused by a distinct species of bacteria, Agrobacterium rhizogenes (99); isolation and culture of a phage specific for A. tumefaciens (35, 58).

The bacterial diseases of cereal crops were investigated by J. B. Kendrick, C. H. Kingsolver, C. S. Reddy and J. R. Wallin. The contributions resulting from their work include: the description and designation of Pseudomonas holci as the cause of leaf spot on corn and sorghum, (34); the determination that Clinton and other oat selections were resistant to the halo blight bacterium, Pseudomonas coronafaciens (36); the description and naming of Xanthomonas translucens var. phleipratensis on timothy (114); the description, naming and determination of the host range of X. translucens var. cerealis found on bromegrass (109); and the demonstration that X. translucens on infested barley, bromegrass and wheat seed will infect the developing seedling (110).

T. F. Yu, S. T. Chao, and W. J. Hooker have studied the bacterial wilt of cucumbers, the bacterial pustule and blight of soybeans, and potato scab, respectively. Two noteworthy contributions were: elucidation of the process of wilting in cucumbers induced by Erwinia tracheiphila and determination of varietal reaction to the pathogen (121); and demonstration of overwintering of the bacterial pustule and blight organisms, Xanthomonas phaseoli var. sojense and Pseudomonas glycine respectively, in soil, soybean seeds and debris (8). The potato scab work will be discussed in a subsequent portion.

Investigations relating to the differentiation and classification of certain phytopathogenic bacteria have been fostered by Melhus. M. K. Patel, G. C. Kent, E. L. Waldee, and V. P. Bhide participated in the work. Their results included: determination that pathogenicity was a necessary criterion for identification of Agrobacterium tumefaciens (72); the proposal of a new family and genus, Erwiniaceae and Pectobacterium, respectively, to include the emended genus Erwinia and related genera (108); and the separation of nine wilt-producing bacteria belonging to four genera into two groups based on their enzymatic activity, nitrogen utilization, and growth temperature range (2).

SPECIAL PHYTOPATHOLOGICAL INVESTIGATIONS: -- From time to time related physiological problems have been investigated. For example, Hoyman (32a) characterized the emetic principle present in scabby barley.

NEW FIELDS OF RESEARCH GIVEN MAJOR EMPHASIS SINCE 1940

Such trends and events as the fabulous increase in soybean acreage, growing interest in improved forage legumes and grasses, and war-time emergency forecasting of potato late blight occurrence led to recent development of research programs in these fields. In the meantime, advances in knowledge of stone fruit viruses made it imperative that Iowa nurserymen begin producing virus-free stocks as soon as possible, the potato scab problem became so acute that an intensive research program was urgent, and Iowa oak trees were suffering from the wilt disease. Research programs dealing with these three problems have also been developed at the Iowa Station since 1940.

POTATO SCAB: -- Although the potato scab problem had been under investigation for some time, particularly in aspects relating to fungicidal control through seed piece treatment, it was not until 1940 that an intensive effort was begun to develop control measures for Iowa's most serious potato disease. After inauguration of the project by Melhus, with the help of G. C. Kent, W. J. Hooker assumed responsibility for the work in 1944. Careful observations revealed that in

Iowa muck soils, Streptomyces scabies could and did parasitize roots and soil-covered stems of potato (32); also that under laboratory conditions, seedling roots of a wide range of plants were susceptible to S. scabies (27). Attempts are being made to induce scab development under controlled conditions in the greenhouse, to lay the basis for testing seedling resistance to S. scabies. A means of observing growth of potato tubers (28) has made possible the direct inoculation of tubers with pure cultures. Thus the progressive development of scab infections has been observed (31).

The effectiveness of control by sulfur and other amendments to Iowa muck soil has been determined (30) and the toxic effect of sulfur has been shown to reduce Streptomyces spp. populations before the soil reaction has changed markedly (104).

As a result of Hooker's interest, other vegetable disease research has been undertaken, notably potato and tomato early and late blight control by fungicidal sprays (29), onion smut control by large dosages of seed protectant chemicals, and sweetpotato pox control by soil amendment with sulfur. In recent years, through cooperation with C. E. Peterson of the U. S. Department of Agriculture in the Department of Horticulture, greenhouse tests have been made for resistance in parents and seedling progenies of potatoes to Phytophthora infestans and viruses. Tomato introductions in the hands of the Plant Introduction Station have been similarly tested for resistance to the Septoria and Alternaria blight pathogens.

SOYBEAN AND FORAGE CROP DISEASES: -- The increasing importance of the soybean in Iowa agriculture, plus the post-war interest in "seeding down" land heavily cropped during war-time, have focused attention on diseases of legumes and forage grasses. Beginning in 1946, A. W. Welch started the intensive program in this field, under projects supported in part by the U. S. Department of Agriculture. Since 1948, J. M. Crall has been carrying forward this work, particularly with legumes. J. C. Gilman and Lois H. Tiffany have helped with some parts. Efforts and contributions have included elucidation of the pod and stem blight and anthracnose complexes on soybeans (102, 118), and of the anthracnoses of red clover (22); also the discovery of a wilt of red clover caused by Fusarium oxysporum (9). Clarification of the role of seed treatment of legumes has been discussed under "seed treatment".

Forage grass disease research was begun by Welch. One of his contributions was the demonstration that "northern" bromegrass was very susceptible to Pythium graminicola (24); northern bromegrass is less likely to develop good stands in Iowa than the "southern" form, which is not so susceptible.

LATE BLIGHT FORECASTING: -- Two factors stimulated the initiation of potato late blight forecasting in Iowa, namely: the prevalence and destructiveness of late blight in the Upper Mississippi Valley region during 1942, and the war-time crop protection emergency.

The destructive potato late blight epiphytotic in 1942 prompted Melhus (46) to propose a study of the temperature-rainfall conditions associated with past Iowa late blight epiphytotics. His studies revealed that for the establishment and spread of the pathogen, relatively low temperature and high rainfall must prevail throughout June and July. Melhus' findings served as a background for the regional late blight forecasting effort which was to follow.

During the national emergency of World War II, plant pathologists were greatly concerned about plant disease control as a means of increasing the nation's food supply. As chairman of the Late Blight Subcommittee of the Upper Mississippi Valley Plant Pathologists' War Service Committee, Melhus led a coordinated effort to report the occurrence and development of late blight in this region. Furthermore, upon receipt of information regarding temperature-rainfall and blight occurrence, forecasts for the region were formulated. Throughout the war emergency period several relatively accurate forecasts were issued and much information about late blight and other diseases was exchanged (47).

Buchholtz resumed a plant disease information exchange in 1946 as the result of an extremely costly tomato late blight epiphytotic in Iowa and the Upper Mississippi Valley. He functioned as an information clearing agent not only for the Iowa extension people, but also for a voluntary group of extension plant pathologists in several States. He continued this work until 1948, at which time the voluntary reporting in the region was undertaken as a part of the U. S. Department of Agriculture regional crop plant disease forecasting project.

In 1948, the U. S. Department of Agriculture Division of Mycology and Plant Disease Survey initiated its crop plant disease forecasting project in the North Central Region. Iowa State College was designated as regional headquarters, and J. R. Wallin was appointed to conduct research basic to tomato and potato late blight forecasting in the North Central States. Within a year after initiation of the project, P. E. Waggoner was employed to assist with the work in Iowa.

The following contributions have resulted from the regional research program:

(a) From a focus of infection, Phytophthora infestans was observed to spread slowly but persistently under conditions that appeared unfavorable (106, 116).
(b) In tomato and potato plots only minor differences were noted between air temperature and humidity at the five-foot and the one-foot levels (105, 116).
(c) Within five Fahrenheit degrees, air temperatures in the instrument shelter were found to represent the temperature of the air surrounding tomato and potato plants, the temperatures of shaded leaves in the daytime and all plant parts at night. However, sunlit plant parts were found to be more than 5° F. warmer than the surrounding air temperature (107).
(d) Fluctuations in amount of late blight were shown to depend upon the frequency of occurrence of favorable temperature and humidity (112, 115).
(e) Isolates of P. infestans have been characterized by their pathogenicity on potato and tomato in the field (113), greenhouse, and laboratory.

These and further efforts supported by this project promise to provide data that will enable the anticipation of late blight epiphytotics with sufficient accuracy to permit growers of the region to intensify or relax fungicidal spray programs on potatoes and tomatoes, with a prospective saving either of the crop or of labor and fungicide cost.

STONE FRUIT VIRUS DISEASES: -- In keeping with the stone fruit industry's demand for virus-free planting stocks from Iowa's wholesale producers (45), there was inaugurated in 1947 a project designed to facilitate production of such virus-free stocks of cherries, peaches and ultimately plums and perhaps all Prunus species and varieties. Thus far, indexed virus-free clones of sour cherries and some sweet cherry varieties have been collected and established. The Mount Arbor orchards of Prunus mahaleb have been indexed and known infected trees discarded.

As a means of determining necessary isolation for virus-free nursery stocks of cherries, samples of Prunus species and varieties cultivated in Iowa nurseries have been virus-indexed at intervals. Some spread was indicated within cherry blocks containing infected trees (21).

One Iowa nursery has been selling cherry trees propagated from indexed scion trees. The three large producers are now in production, although the lack of virus-free understocks remains as an impediment in the program. Understock production is largely in the Pacific Coast States of Washington, Oregon and California.

This work has been under the supervision of W. F. Buchholtz, with H. C. Fink and O. F. Hobart Jr. as student contributors.

OAK WILT: -- Investigation of the oak wilt disease was begun in 1943, at which time the Iowa State Conservation Commission provided resources to determine the cause of oak tree decline in Iowa's State parks. S. M. Dietz, J. W. Barrett, R. A. Young, G. L. McNew, Paul Hoffman, and W. H. Bragonier have at various times been associated with this project. Contributions to date include confirmation that Chalara quercina is the cause of oak wilt in Iowa, and determination of its prevalence in Iowa oaks, as well as its host range under greenhouse conditions (12).

EXTENSION PROGRAM

The Iowa Extension program in plant pathology has been modest in personnel and resources expended, but its activities have influenced agricultural practice in Iowa and the Midwest.

PROMOTION OF ADOPTION OF DISEASE-RESISTANT VARIETIES AND DISEASE-FREE SEED STOCKS: -- The Iowa State College Agricultural Extension Service has long been active in promoting the use of disease-free seed stocks and disease-resistant crop varieties. Adoption of yellows-resistant cabbage and rust-resistant Washington asparagus in southeastern Iowa was promoted by Melhus and his associates before plant disease teaching, as such, was a well established activity of the Extension Service.

Discoveries by workers elsewhere that viruses cause "running-out" of potatoes, and the establishment of production of virus-free seed stocks in northern and western States, formed the basis for teaching growers and gardeners the value of "certified" (disease-free) seed potatoes.

Early success with such projects soon led to the establishment of a position for a plant pathologist in the Extension Service. After a short time of service by R. O. Cromwell, R. H. Porter was appointed to this post in 1921. Except for an interim spent in China, during which time Morrison Burns served, Porter was Extension Plant Pathologist until 1933. Then for a time D. V. Layton served in that capacity. Later came J. H. Standen, E. L. Waldee, and D. M. Coe. A. P. Sherf is the present Extension Specialist in Plant Pathology. From time to time, E. P. Sylvester has aided in the program as the occasion demanded. Since 1936, C. S. Reddy has devoted part time to Extension plant pathology.

Assignment of personnel resulted in expansion and intensification of the plant pathology program in Extension. In addition, the newly acquired phytopathological research farms at Kanawha and Conesville offered unusually effective facilities for field demonstration. One such demonstration at Kanawha showed that wilt-resistant flax varieties would actually produce satisfactory crops for five successive years on the same field, while susceptible varieties failed after the first year. Dissemination of such information played a large role in resumption of flax growing in Iowa, an enterprise which, with war-time prices, reached an all time high of over 350,000 acres in northern Iowa in 1943.

By participating in field demonstrations and dissemination of information, verbal and printed, Extension plant pathologists have helped promote the use of the crown rust-resistant oat varieties available to Iowa farmers since 1940. An additional 110 million bushels of oats produced by Iowa farmers during the years 1941 to 1945 were in part the result of an intensive war-time Extension campaign (1) to promote adoption of the crown rust-resistant varieties responsible for the additional yield.

Through Extension activities at Conesville in southeastern Iowa, availability and performance of wilt-resistant varieties of watermelons have been made known to growers in that area. Nearly all watermelons grown in that area since 1930 have been of such wilt-resistant varieties.

PROMOTION OF FUNGICIDE SEED TREATMENT AS AN AGRICULTURAL PRACTICE, AND THE ADOPTION OF CONVENIENT AND ECONOMICAL METHODS OF SEED TREATMENT APPLICATION: -- The first bulletin recommending seed treatment of corn was published by the Iowa State College in 1927 (54). The adoption of seed treatment as an agricultural practice in Iowa has paralleled the striking growth of knowledge in this field and the development of suitable fungicide seed dusts.

The first objective of cereal seed treatment, smut control (with formaldehyde), was sponsored by Iowa State College as early as 1918 (33). The advent of the organic mercury dusts for control of smut and seedling blight caused by seed-borne pathogens was the basis for an extensive series of demonstrations of the economic value of seed treatment and of the revolving barrel and gravity methods of application, by Porter and Layton (78). During the late 1930's, with the development of machines for continuous application and of knowledge that seed treatment could protect the germinating seed from damage by soil-borne pathogens, there was a tremendous increase in custom seed cleaning and treating in farm and city elevators. Practical demonstrations on a commercial basis at Kanawha and Conesville played a large part in promoting both seed treating and seed cleaning, the latter a worthwhile weed control as well as disease control practice. Custom seed cleaning and treating has been an annual demonstration at Kanawha since 1935. At least a million bushels of cereals, corn, and soybeans have been so processed there. In 1950, there were 240 seed cleaning and treating stations in Iowa.

Some form of seed treatment fungicide is applied by hybrid corn processors to practically every bushel of seed corn produced or sold, or both, in Iowa. Original promotion of this procedure was in part by Extension plant pathologists in Iowa and other States. There is no longer a need to induce seed companies to treat corn seed, but they have been constantly advised about latest developments in fungicide chemicals and formulations and methods of application by Iowa Extension plant pathologists.

Although development of wilt-resistant varieties was basic to the resumption of flax production in northern Iowa, seed treatment, by insuring good stands with early plantings, was a large factor in the successful wartime production of large flax acreages in northern Iowa. Burnett and Reddy presented data on the first successful flax seed treatments (7). Demonstrations and reports (84) of experiments at the Northern Iowa Experimental Association farm at Kanawha were the basis for adoption of flax seed treatment as an agricultural practice in Iowa, and possibly for other flax-producing States.

PROMOTION OF SPRAYING FOR FRUIT AND VEGETABLE DISEASE CONTROL: -- Iowa fruit and vegetable growers and gardeners are regularly advised as to new and appropriate

disease control measures. Commercial growers of apples and potatoes practice scab and early and late blight control, respectively, according to recommendations by plant pathologists, made through facilities provided by the Extension Service.

LATE BLIGHT FORECASTING: -- The potato and tomato late blight forecasting initiated in Iowa during the war was followed closely by the Extension Services of Iowa and surrounding States. They used the predictions to stimulate growers to practice more effective spraying or to refrain from spraying and save valuable materials and scarce labor, whichever the local situation warranted. The three years' war-time service has been summarized (47), and a saving of several million bushels of potatoes estimated for the region.

VICTORY GARDEN PROGRAMS: -- Another significant war-time Extension activity by Iowa plant pathologists was participation in the victory garden campaign. Through personal appearances at education meetings and through bulletins, the press and radio, the place of disease control in home gardening and orcharding was made known to victory gardeners throughout the State.

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